SPECIFICATION

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[Mast for Handling a Coiled Tubing Injector]

Cross Reference to Related Applications

This application claims priority to related provisional patent application number 60/334,868 entitled, "Mast for Handling a Coiled Tubing Injector"filed October 30, 2001, which is incorporated herein by reference.

Background of Invention

[0001] Coiled tubing injectors are used to run in and out of well bores continuous pipe. Continuous pipe is referred to as coiled tubing because it is stored on large reel. Though coiled tubing can be used for drilling operations, it is ideal for servicing existing wells. It can be run in and out of the well bore much faster than conventional, jointed pipe. Furthermore, no complex drilling rig or other structure needs to be erected at the well. A crane is transported to the site, along with the blow out preventer, coiled tubing and coiled tubing injector, on the back of a truck. The crane is used to hoist and hold a blow out preventer and coiled tubing injector over the wellhead during servicing. With a conventional boom, the crane relies on a cable and winch to raise and lower the injector and blow out preventer. A hook at the free end of the cable connects the injector to the cable.

Summary of Invention

[0002] Winches and cables used on the cranes that hoist the injector over the wellhead are prone to failure. Failure of any of these elements can result in significant damage to the wellhead and creates a safety risk.

[0003] Unlike a conventional crane, a mast according to the invention raises and holds an injector or other oil field equipment over a wellhead using at least two telescoping

arms. The equipment is placed between the arms, near a top end of the arms. Telescoping the arms raises the injector. Pivoting the mast moves the injector or other equipment over the wellhead. Such a mast need not utilize elements such as winches and cables to hoist the oil field equipment. Therefore, it can be made less susceptible to failure.

[0004] According to one aspect of a preferred embodiment of the invention, each arm is extended and retracted by use of a jackscrew. Each jackscrew preferably has a low pitch that makes it self-locking, thereby preventing collapsing of the legs under the weight of an injector if power is lost or interrupted. For arms with more than two segments, a lifting chain can be used to lift each additional segment. For example, in an arm with three segments, a lifting chain anchored at the top of the first segment extends up over a sprocket or pulley on top of the second segment and then back down to attach to a bottom of the third telescoping segment. The lifting chain pulls the third segment out of the second segment the second segment is pulled out of the first segment.

[0005] Another aspect of a preferred embodiment of the invention is a transportable multi-arm mast that pivots to a stowed position for transport with an injector and blow out preventer between the arms of the mast. During storage or transport, the injector and blow out preventer tilt backwards along with the mast. When deployed, the mast, injector and blower out preventer are moved to an upright position, preferably in a single action, with the injector positioned so that it can be picked up by the mast and then lowered onto the top of the blow out preventer for assembly. Once assembled, the injector and blow out preventer can then be raised and placed over the wellhead.

[0006]

Another aspect of a preferred embodiment of the invention includes an arrangement for preventing an extendable mast from being pivoting too far (for example, to a point of potential instability) based on how far the mast is extended. The further the mast is extended, the greater the leverage is of a load carried by it. One particularly advantageous application is an extendable mast that pivots by means of a mechanism such as a hydraulic cylinder. The hydraulic cylinder is at one end coupled to the mast and at the other end to a movable mounting on a base or

platform for the mast. The mounting is moved based on the degree to which the mast is extended. The mounting is posited where, with the fullest extension of the hydraulic cylinder, the resulting degree of pivot of the mast is at or less than a predetermined maximum angle for the amount of extension of the mast. Thus, the extendable mast can be prevented from being extended too far based on its extension. The relationship between the position of the mounting and extension of the mast may be adjustable based on the weight of an actual load carried by the mast, or may be set based on a maximum or expected load. Furthermore, the arrangement is self correcting. In the given example, if the hydraulic cylinder is already fully extended, the mast will be automatically pivoted to a more upright position as the mast is extended by movement of the mounting.

[0007] The accompanying drawings illustrate an example of a mast for handling a coiled tubing injector incorporating preferred embodiments of various aspects of the invention.

Brief Description of Drawings

[0008] Figure 1 is a perspective view of one embodiment of a mast assembly for handling a coiled tubing injector.

[0009] Figure 2 is a front view of the mast assembly of Figure 1, with the mast assembly fully extended.

[0010] Figure 3 is a section of Fig. 2, taken along section lines 3-3.

[0011] Figure 4 is a section taken through Fig. 2 along section lines 4-4.

[0012] Figure 5 is a side view of one embodiment of a mast assembly, injector and BOP prepared for transport on a trailer;

[0013] Figure 6 illustrates a cross section of one embodiment of a first segment;

[0014] Figure 7 illustrates a cross section of one embodiment of a first segment and one embodiment of a second segment;

[0015] Figure 8 illustrates a perspective view of one embodiment of a second segment;

[0016] Figure 9 illustrates a perspective view of one embodiment of a third segment telescopically extending from one embodiment of a second segment;

[0017] Figure 10 illustrates a perspective view of one embodiment of a second segment telescopically extending from one embodiment of a first segment;

[0018] Figure 11 illustrates a side view of one embodiment of a mast assembly with a plurality of its segments extended;

[0019] Figure 12 is a perspective view of one embodiment for synchronizing pivoting of a mast assembly; and

[0020] Figure 13 is a perspective view of one embodiment for synchronizing operation of jack screws during telescoping of a mast assembly.

Detailed Description

[0021] Like numbers refer to like elements in the following description.

[0022] Figures 1-3 are various views of an exemplary embodiment of a mast assembly for suspending coiled tubing injectors and other equipment over a wellhead. In this embodiment, mast assembly 10 includes two generally parallel telescoping arms 12 and 14. Each arm includes a plurality of telescoping segments, labeled 12A, 12B and 12C and 14A, 14B and 14C, respectively. The arms are shown fully retracted in Figure 1: segments 12C, and 14C are drawn or received inside segments 12B and 14B, respectively; and segments 12B and 14B are drawn into segments 12A and 14A, respectively. The mast assembly is shown in a fully extended position in Figures 2 and 3.

[0023] Cross member assembly 16 extends between, and is connected to, segments 12C and 14C so that the distance from the base of the mast assembly to the cross member assembly increases as the mast assembly telescopes outwardly. Coiled tubing injector or other equipment to be held over a wellhead is attached to the cross member assembly when the mast is in a retracted position and then raised higher by extending or telescoping the mast assembly. The mast assembly 10 is attached to a frame 18 using a pivoting mounting system, so that the mast assembly can be pivoted in a forward and aft direction indicated by arrow 20 in Figure 3. Frame 18 is intended to

be representative of a stable mounting structure, such as a rear of a truck or trailer stabilized with outrigger jacks 22 or a platform. Pivoting the mast forward allows the mast assembly to place the coiled tubing injector over other equipment over the wellhead.

[0024] It is preferred, though not necessary for achieving advantages of other aspects or features of the invention, that the coiled tubing injector or other equipment be attached as near to the top of the mast as possible to achieve better control and reduce the necessary overall height of the mast. However, if the height of the equipment is less than the distance to the cross member assembly with the mast fully retracted, it may not be possible to attach the equipment directly to the cross member assembly with a minimum of distance. Though a winch, crane or other conventional mechanism could be used, these mechanisms are prone to failure. Furthermore, as will be subsequently described, it is preferable to be able to transport or store the coiled tubing injector or other equipment with the mast assembly without having to affix it to the cross member assembly until they are ready to be used. This ability enables, for example, a coiled tubing injector and a substantially taller blowout preventer to be transported or stored between the arms of the mast assembly and then joined prior to them being held over and joined to the wellhead. In order to accommodate both a coiled tubing injector and a substantially taller blow out preventer, the exemplary embodiment illustrated in the drawings includes a mechanism for initially hoisting the equipment, in particular a coiled tubing injector in well workover applications, for attachment to the cross member of the mast assembly. This mechanism takes the form of a fixed-length cable 24 that is releasably anchored or attached to the first segment of an arm or to something that does not move as the mast assembly is extended. The cable is looped around an element that moves with the top of the mast, such as around a pulley on the top of the mast assembly or that is part of the cross member assembly. As the mast extends, the cable lifts the equipment up to the cross member assembly. When the equipment reaches the cross member assembly, the cable is released from its anchor.

[0025] In the illustrated example, fixed length cable 24 is releasably anchored to flange 26 and it extends around pulleys 28 and 30. Two pulleys are used, as it is preferable, for reasons subsequently described, to be able to move the position of the cable

laterally between arms 12 and 14. Pulley 30 is therefore disposed on a lateral transport mechanism at the top of the mast assembly. In the exemplary embodiment, this lateral transport mechanism takes the form of a trolley 32 that moves on a round cross member 34. The cross member serves as a track. The trolley and the cross member are round so that the trolley is able to orient itself to be perpendicular to the ground as the mast pivots forward and aft. Other types of lateral transport mechanism could be used to move the position of the cable, though perhaps with the advantages of this particular mechanism.

[0026] In order to simplify operation and provide a secure connection to the mast of the coiled tubing injector or other equipment (not shown in these views), cable 24 has at the end opposite of its anchor a latching member 36 that is used to connect the cable to the coiled tubing injector or other equipment. This latching member cooperates with latch 38 to securely hold the equipment to the cross member assembly. The cable extends through the latch. As it is preferred to have the position of the cable to be moved laterally, the latch is part of or attached to a trolley. As the cable hoists the coiled tubing injector or other equipment into position, a portion of latching member 36 is received within latch 38. When it is received and the latch actuated, the equipment it is securely connected to the cross member assembly. Preferably, the latching is automatic, with a spring loaded latching mechanism being triggered by the latching member entering the latch.

[0027] Referring now also to Figures 4 and 5 in addition to Figures 1-3 a screw 40 and lifting nut 42 is preferred for lifting each second segment, 12B and 14B, out of each first segment, 12A and 14A, respectively. However, other mechanisms, such as a hydraulic cylinder or a motor driven chain, could be used to telescope the arms without sacrificing advantages of other aspects of the exemplary embodiment of the mast assembly or the invention. One reason that a screw is preferred is that a screw can be easily made self-locking by use of low pitch threads. Thus, friction between lifting nut 42 and the screw threads can be used to prevent rotation of the screw under the load of the coiled tubing injector or other equipment if power is lost. Another reason is that low pitch threads also provide a high degree of leverage, allowing less powerful motors to be used to turn the screw.

[0028] It is also preferred that both arms have a lifting mechanism, such as the screw, for well servicing applications using coiled tubing. However, not every arm may require a lifting mechanism, depending on the use of the mast assembly. The sectional views of Figures 3, 4 and 5 are of arm 12. Sectional views of arm 14 would be substantially similar. Rotating the screw either raises or lowers lifting nut 42, depending on the direction of rotation of the screw. As shown clearly in Figure 8 and 9, flanges 43 of the second segment 12B rest on lifting nut 42, which allows the segment to be lifted and lowered (under the force of gravity) by raising or lowering the lifting nut. Note that the screw 40 and the first segment are omitted from this view. Lifting nut may, however, cooperate with segment 12B in any manner to facilitate raising and lowering of the segment.

[0029] The screw is preferably placed in tension when the mast assembly is loaded, and not in compression. Therefore, the screw is supported by upper mounting 44, with lower mounting 46 assisting with holding it in place. The lower mountings 46 can also be seen clearly in Figure 6, and the upper mountings 44 in Figure 7.

[0030] Referring now to Figures 6 and 7 in addition to Figures 1-5, each of the third segments 12C and 14C are lifted from second segments 12B and 14B, respectively, using a lift chain 47. The lift chains 47 are anchored, respectively, to each of the second segments 12B and 14B, preferably near the bottom of those segments. As best seen in Figure 3, the chain 47 on each arm loops around a pulley 49 located at the top of the second segment of the arm, and then attaches to the bottom of the third segment. Extension of each of the segments 12B and 14B thus automatically lifts the third segments 12C and 14C out of the second segments. Though a lifting chain is preferred for its simplicity and reliability, other mechanisms can be used to lift each of the third segments out of the first segment. If the arms contain additional segments, these segments could also be extended using lifting chains.

[0031]

Referring briefly now also to Figure 8 in addition to Figures 1-6, rotational power is delivered to the screws by, for example, at least one, motor. In the exemplary mast assembly, two hydraulic motors 48 are used. However, other types of motors could be used. Power is transferred to the screws by means of chains 50. However, other types of transmissions could be used. Chain 52 extends between the two motors and

ensures synchronous operation of the transmissions, and thus also synchronous rotation of each screw. Chain 52 is partially obscured by chain guard 54.

[0032] Referring now to Figures 1-6 and 9, depending on the height and angle of the mast assembly, a heavy load will generate a substantial moment about the top portion of the first segments 12A and 14A of the telescoping arms 12 and 14, resulting in the second segments imposing substantial lateral force on the first segments of the telescoping arms at the tops of the first segments and where the bottom of the second segments push against the inside of the first segments. These loads create friction between the second segments 12B and 14B and on the first segments 12A and 14A, respectively, thus inhibiting movement of the second segments with respect to the first segments. In order to reduce friction between the two lower segments in each arm, the first segments 12A and 14A of each arm in the exemplary embodiment are each provided with a set of roller bearings 56 near the top of the first segments, where the bearings act against the outside of the second segments at the points where the segments tend to pivot. Furthermore, the second segments 12B and 14B each also include a set of roller bearings 58 near their lower ends that act against the inside surface of the first segments. As the load is not as great, low friction surfaces or pads are used as bearings at the junction of the second segments 12B and 14B with the third segments.

[0033] Referring to Figures 1-3 and Figure 10, mast arms 12 and 14 are, as previously indicated, mounted to support frame 18 so that they are permitted to pivot in the forward and aft directions. The mast assembly pivots forward to position the equipment over a wellhead. It preferably also pivots rearward so that it can laid relatively flat for transport and/or storage. Therefore, each arm of the mast is attached to frame 18 with a pivoting connection, such as mounting 60. The mast assembly"s is raised by, and its inclination controlled at least in part, by a pair of hydraulic cylinders 62. Hydraulic cylinder"s are preferred, for several reasons, to support and to control the degree of tilt of the mast assembly. First, they be retracted far enough to accommodate the mast being laid nearly completely flat when pivoted in the aft direction. Second, they can be powered using a hydraulic power source that typically can be found on trucks. Third, in the event of loss of power, they will not collapse.

[0034] However, an extending mechanism with a mechanical (e.g. screw) rather than hydraulic lift or cylinder, for example, or other types of mechanisms (e.g. a cable and winch) could be substituted, without loss of advantages of other features of the mast assembly. For example, the mast assembly could be supported, and its angle could be changed, by a non-extendable support member pivotally attached to the mast assembly at one end and a sliding mounting at the other end. However, the amount of travel of a sliding mounting may make mounting the mast on the back of a truck difficult or impossible. Another example is a support structure with articulating members. Structures with articulating members are, however, inherently more expensive to build, require more maintenance, and are more prone to failure than a hydraulic cylinder. A winch and cable could be used to control the tilt of the mast assembly, but a winch and cable is susceptible to breaking and cannot be easily used to raise the mast assembly from a stowed position.

[0035] If the mast assembly is mounted, for example, to the back of a truck, there will be a point at which the moment force about the base of the mast assembly, created by the weight of mast and equipment hanging from it, multiplied by the leverage of the mast, cannot be balanced by the structure (vehicle (truck or trailer) or stationary) on which it is mounted. If this moment force is exceeded, the mast assembly and will become unstable and tend to tip over. Lowering the mast lowers this moment force. Thus, when the mast assembly is not fully extended, the mast could be tilted further forward without loss of balance or stability. The angle theta, which is marked on Figure 3 and represents the forward tilt of the mast assembly, has a maximum value for mast assembly stability that depends on extension of the mast and load. One approach to preventing too much tilt of the mast assembly for the support structure on which it is mounted is to fix the maximum forward angle of the mast assembly based solely on a maximum load with the mast assembly fully extended. However, this approach gives up use of the mast at greater forward tilts that would otherwise not cause tipping, which may be desirable.

[0036] It is therefore preferable to have each of the hydraulic cylinders 62 (or, if cylinders are not used, other mechanism for pivoting the mast or arms) coupled or connected at one end to a sliding mounting that limits the forward tilt of the mast assembly when the hydraulic cylinders or other mechanism is fully extended. The sliding mounting

could be located either on a base to which the mast is coupled or on the mast itself. The position of the sliding mounting, and thus of the base or ends of the hydraulic cylinders, are automatically determined based on the extension of the mast assembly. As the mast assembly is extended, the sliding mountings are moved aft, away from the mast assembly as necessary to avoid having the angle of the mast assembly exceed the maximum permitted angle for the degree or length of extension. In its simplest form, this automatic correction assumes that hydraulic cylinders, or other support structure or mechanism, is fully extended and the maximum permitted load is being held by the mast assembly. A programmable controller is preferably used to automatically position the sliding mounting. If desired, the programmable controller could also take into account the actual load on the mast when positioning the sliding mounting. The actual load could be, for example, input into the controller or obtained from a load sensor. It could also take into account the degree of extension, or position, of the support structure or mechanism (e.g. the hydraulic cylinders) using a sensor.

[0037] In the exemplary embodiment, sliding mounting 64 takes the form of a trolley 66 that travels on two rails 68. The base of a cylinder 62 is pivotally connected with the trolley. In order to move and position each trolley, it is coupled to a screw 70 through a nut (not visible). Turning the screw moves the nut and thus also the trolley. One or more motors are used to turn the screw. In the illustrated example, the motors are hydraulic motors and rotary power is transmitted to the screw by a chain. Hydraulic cylinders or other mechanisms could be substituted for the screws to position the trolleys. To synchronize the two motors, and thus also movement of the trolleys, the outputs of the motors are coupled through timing chain 74. Other means for coupling the outputs of the motors for synchronization can be used. Other forms of sliding mountings could also be used.

[0038] Referring now to Figures 1-3, 11 and 12, the mast assembly 10 preferably also includes a support structure or mounting for holding a blowout preventer and coiled tubing injector (not shown in these views), or other equipment that is to be hoisted by the mast assembly and positioned over a wellhead. This equipment is positioned on the support, between arms 12 and 14 of the mast assembly. The support, and thus also the equipment, preferably tilt with the mast assembly in at least the aft direction

for transport. Support 76 of the exemplary embodiment is desired to carry a coiled tubing injector 78 and a blowout preventer 80 (which are shown only in Figure 11). The coiled tubing injector is, as is conventional, held within a cage or frame 82. It also has attached to it a goose-neck support assembly 84 for supporting the coiled tubing between the injector and a reel on which it is wound. Support 76 has four posts 88, which are received into openings in the bottom of frame 82 of the coiled tubing injector. The support also includes flange 90, on which the blowout preventer rests. The flange is mounted on a sliding structure 92 so that it can be moved closer to the center between the arms 12 and 14 of the mast assembly. Two of the four posts 88 are also mounted on the sliding structure 90, but only because it simplifies the design. The posts could be mounted in a fixed position if desired. The sliding structure is comprised of two sleeves 94 connected by a cross member 96. The sleeves slide on round members 98. A hydraulic cylinder 100 is used to move the sliding structure. Though the illustrated support and sliding structure have certain advantages, other support and sliding structures can be used to support and move the equipment for transport, handling and/or storage.

[0039] For well workover and similar operations, mast assembly 10 first lifts the coiled tubing injector 78 off of support 76. In order to lift the injector off of the support, trolley 32, shown in Figures 1 and 2, is moved so that the cable 24 and latching member 36 are centered over the coiled tubing injector and its frame. As described above, the coiled tubing injector is initially hoisted to the cross member assembly 16. The coiled tubing injector is raised further until there is sufficient clearance for the blowout preventer 80 can be placed under it. The blowout preventer is then moved over by operation of the sliding structure 90. If necessary, the coiled tubing injector can also be moved with trolley 32 so that the coiled tubing injector and blowout preventer are centered with respect to each other. The blowout preventer is then joined or attached to the coiled tubing injector, and the combination is then further lifted and moved over the wellhead by extending and tilting the mast assembly 10. Once over the wellhead, the combination is then lowered and joined with it.

[0040] Referring now to Figures 13 and 14, mast assembly 10 is used to particular advantage when mounted on a self-contained truck, such as truck 102, that is used for well workover operations. The mast assembly 10 is preferably mounted on the rear

of the truck. In Figure 13 the mast assembly is laid flat for transportation and storage in order to provide a lower clearance. Figure 14 illustrated the mast assembly in a fully erect and extended position, with coiled tubing injector 78 joined with blowout preventer 80 and suspended from the cross member assembly 16. The truck preferably also carries a reel 104 of coiled tubing. It may include a control cabin 106 that elevates, as shown in Figure 14, above the reel for a better view of the wellhead. As shown in Figure 13, coiled tubing injector 78, in its frame 84, and the blowout preventer are mounted on support 76 for transportation. The support 76 is tilted with the mast assembly so that the coiled tubing injector and blowout preventer are also laying relatively flat, like the mast assembly 10. The truck also includes a hydraulic power pack for supplying hydraulic fluid under pressure to the various hydraulic motors used in the system.

[0041] As shown in Figures 1 through 3 and 12 through 14, the mast assembly is optionally supplied with a small crane 110 for loading the coiled tubing injector and blow out preventer on the trailer. The crane can be easily folded up, as shown in the various views, to reduce its profile.

[0042] What is claimed is: